GEOmetry LABoratory (GEOLAB) Surface Modeling and Grid Generation Technology and Services

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Abstract

The facilities and services of the GEOmetry LABoratory (GEOLAB) at the NASA Langley Research Center are described. Included in this description are the laboratory functions, the surface modeling and grid generation technologies used in the laboratory, and examples of the tasks performed in the laboratory.

1 Introduction

Discussion of the concept of GEOLAB began in the late 1980s when computational fluid dynamics had demonstrated the capability to produce accurate and relatively inexpensive flow fields about complex geometries. The bottleneck for obtaining solutions, however, was the amount of time required to prepare the surface geometry and grid data for the flow field solvers. Typically, several months of intense activity was required to produce geometry data after which the first flow field solution could be obtained in a matter of hours. A similar amount of time was required each time a new configuration was undertaken. Computer-Aided Design (CAD) software and emerging grid-generation software potentially could increase the surface and grid data productivity, but it had to be organized and integrated into the computational environment. The concept of GEOLAB was to centralize those geometry activities requiring specialized (but broadly applicable) talents, software, and hardware and to decentralize those tasks which required individual engineering tuning. Training and communications were and still are the essential ingredients for the concept.

GEOLAB was initially formed in 1990 to support Langley researchers performing Computational Fluid Dynamics (CFD) analyses. GEOLAB focuses on high performance workstation hardware, CAD and grid generation software, and the skills to efficiently produce geometry data. The main goals of GEOLAB are to improve the efficiency in performing geometry related functions such as surface modeling and grid generation, to promote technology development of new geometry techniques, and the transfer of such development to customers both internal and external to the Langley Research Center. In the past four years, GEOLAB has expanded its capabilities in order to support projects involving conceptual design, model production, structural analyses, materials, multi-disciplinary optimization, and reverse engineering.

Since its inception GEOLAB has reduced the time to perform a typical grid generation task from 820 manhours to 95 manhours In addition, this also represents an approximate "order of magnitude" decrease in the cost of grid generation for a typical project.

2 GEOLAB Resources

GEOLAB is equipped with state-of-the-art hardware and software. The hardware includes 10 high-end Silicon Graphics workstations and 7 NCD X-terminals. The workstation consoles are located in a communal area near desk space where the X-terminals are located. A CYBERWARE laser digitizer and a Calcomp Flatbed Digitizer are also available in GEOLAB to enable mathematical surface reconstruction from physical objects and blueprints. The equipment is used primarily for the production of surface models, computational grids, and for software development; users must be involved in surface modeling or grid generation projects to qualify for accounts. In addition, researchers working on parallel algorithms are given accounts in order to test their algorithms in a clustered workstation environment during non-prime hours. There are over 75 users including the GEOLAB team.

The GEOLAB software includes CAD, grid generation, and visualization tools that have been developed or acquired to facilitate the generation and analysis of surface representations, surface grids, and volume grids for both structured and unstructured analysis techniques. Among the tools currently in use in GEOLAB are: GRIDGEN, ICEM-CFD, VGRID, GridTool, CSCMDO, SurfACe, RAPID, and SCAFFOLD. Each of these software tools is briefly summarized in Appendix A.

A key element to productivity and efficiency in GEOLAB is the integrated computing environment provided by the system administration techniques employed. All user files and software files are cross-mounted so that all utilities are available on all machines. Network licenses are purchased when buying commercial software so that no workstation needs to be reserved for a particular function. Passwords are common across the machines. Access to general-purpose tools and utilities such as printers, manual pages, electronic mail, editors, etc. are available from any machine. An attempt is made to keep the workstations at the same revision of the operating system and to keep the amount of memory and CPU type uniform across the cluster. In general, the user is presented with the same environment and resources transparently, no matter which workstation is used.

The hardware and software are matched with a team of skilled specialists consisting of 5 civil servants, a National Research Council fellow, a university post doctorate, two university doctoral candidates, and 7 NPS contractors. The members of the team have mechanical or aerospace engineering, computer science, and mathematics backgrounds. The contractor team members are responsible for performing most of the surface modeling and grid generation tasks in response to the Research Technology Group at Langley and other external organizations. Also they are heavily involved in the development of specialized software tools that are needed to improve the efficiency of the process or to provide a custom tool to support a research project initiated in the Research Technology Group at Langley. The civil service personnel are involved in the development of new methodologies for surface modeling and grid generation, data transfer and computing environment issues, and the administration of GEOLAB. While the expertise of team members lies in different specialty areas, most are cross-trained in all the software tools used in the laboratory in order to maintain a cohesive and flexible response to customers.

GEOLAB is currently located in the Scientific Applications Branch of the Information Systems Division, Internal Operations Group at the NASA Langley Research Center. The GEOLAB team has access to advanced tools for scientific data visualization, data base management, image processing, and high performance computing as a part of the Scientific Applications Branch. In addition, the team has ready access to other services within the Internal Operations Group that support wind tunnel model production and experimental testing. The availability of these capabilities greatly enhance both the scope of problems GEOLAB is able to address and the quality of the resulting work performed in GEOLAB.

3 GEOLAB Functions and Experiences

GEOLAB functions can be divided into 4 categories: (1) production surface modeling and grid generation tasks; (2) software development supporting surface modeling and grid generation; (3) research into new technology; and (4) training and technology transfer.

3.1 Surface Modeling and Grid Generation Tasks

GEOLAB performs a wide variety of production surface modeling and grid generation tasks enabling researchers to effectively proceed with their computational analyses. The details of these tasks include data repair such as adding missing features; blending features together; and reconstructing surface models from grid points, blueprints, or measurement of existing physical models. Other tasks include preparation of surface and grid data for parametric studies and production of denser or sparser grid sets.

Most production surface modeling and grid generation tasks take 2 to 6 weeks to complete depending on the complexity of the configuration, the accuracy required to support the intended analysis tool, the nature and condition of the input data, and the format of the output data. Projects in which the input data is not in electronic format, i.e., coefficients or points in a design book, blueprints, or models for which a high degree of accuracy is needed to support Navier-Stokes analysis may take 6 to 12 months to complete. Usually these projects are only undertaken if several groups of researchers have need for the data. GEOLAB also provides support for much smaller tasks such as data conversion, geometry visualization, and quick data verification for researchers. These tasks usually require anywhere from an hour to 3 days. Tool development tasks require anywhere from 2 to 12 months development time. The tasks are usually broken down into sub-tasks with specific deliverables and schedule. The researcher is involved at an early stage as the requirements are decided upon and as each major sub-section is developed and demonstrated. This involvement also provides several points at which priorities may be re-assessed and adjusted.

3.2 Software Development

The software used in GEOLAB is licensed from commercial companies, obtained free from government sponsored development projects, or created in-house. The choice of which source to use is based on availability, cost and timeliness. CAD software, as a rule, is always licensed. Grid generation software is usually acquired from freeware sources or created in-house. Special purpose software is almost always created in-house. The programs SurfACe, GridTool, SCAFFOLD, and CSCMDO described in Appendix A are representative of the software developed in GEOLAB. The rationale for creating them in-house follows.

SurfACe is a software package used to evaluate the quality of surface grids. It allows visualization of the surface of multi-component configurations and the characterization of several grid quality functions on the surface. Since SurfACe is tailored to evaluate surface grid quality, it has been designed to expedite these operations. This gives SurfACe its primary advantage over systems such as FAST, a freeware visualization system or FIELDVIEW, a commercial visualization system.

GridTool is a surface grid generation program originally written to prepare unstructured surface grids for the VGRID unstructured volume grid generation system. GridTool has evolved to be a versatile utility bridging the gap between CAD geometry and grid generation programs. GridTool creates grids on patches that are projected to the CAD description, thereby easily generating grids that are on the precise CAD description of the surface.

SCAFFOLD is an interactive program written to recreate numerical geometry models from measured data obtained by scanning physical models with the CYBERWARE laser digitizer. SCAFFOLD provides the bridge between measured models and CAD models. It is an example of the specific software developed in GEOLAB to meet a specialized need.

CSCMDO is an automatic grid generator that operates in a batch environment. It is designed so that the need for human intervention in the design optimization loop is eliminated.

3.3 New Techniques for Surface Modeling and Grid Generation

The establishment of GEOLAB was based on many prior years of grid generation research in the Analysis and Computation Division at the Langley Research Center. The development of new techniques is now an integral part of GEOLAB. There are two in-house project under way: (1) The rapid generation of airplane configurations using engineering parameters, and (2) The development of high aspect ratio unstructured grid generation techniques.

3.4 Training and Technology Transfer

Besides surface modeling and grid generation tasks, GEOLAB also provides training in the software tools used in the lab developed under contract for NASA to researchers at LaRC, other NASA centers, government agencies or industrial partners. Included in the list of tools supported to this extent are: GRIDGEN, GridTool, and CSCMDO. GEOLAB team members along with members of the Transonic Aerodynamics branch have presented one or two grid generation classes a year to present the elements of grid generation, the use of GRIDGEN for structured grids, and the use of VGRID for unstructured grids. These classes include hands-on tutorials. During these sessions GEOLAB is dedicated to the training class to allow the participants access to the hardware. The lab environment is ideal for this type of activity with 10 machines in one area and easy access for the instructor. One-on-one training is provided on request in the use of specialized tools like GridTool, CSCMDO and RAPID as the need arises. Over 200 people have been trained by GEOLAB since its inception.

GEOLAB is committed to technology transfer to the Langley researchers, other government and university centers, and U. S. industry. In addition to offering training, GEOLAB makes available its software tools. SurfACe, GridTool, CSCMDO, VOLUME, and RAPID are available upon request. By far, the most requested software is GridTool. At this writing, 80 copies have been distributed throughout the United States, in addition to its use at Langley.

Cooperative Agreements between GEOLAB and outside organizations can be made to produce surface models and grids. GEOLAB staff will demonstrate the software tools and methodologies on geometry problems of interest to the requester. Agreements of this nature have been entered into with David Taylor Research Labs, Boeing Company, McDonnell Douglas Corporation, and Ford Motor Company. These agreements are normally coordinated through the Technology Applications Group (TAG) at Langley

4 Future Directions

There are several problem areas that GEOLAB would like to address in the future. The most important is the length of time it currently takes to produce a surface representation and computational grid for analysis. As was stated earlier, it usually takes 2-6 weeks to prepare the geometry and volume grid for a detailed Navier-Stokes analysis. To meet the needs of industry, this time must be reduced to hours. To meet this need, better tools are needed to run in a more automatic fashion with little or no human intervention. In addition, these tools must also be flexible and robust enough to handle computations dealing with a high degree of complexity.

Further work is indicated in other specific areas in which GEOLAB is currently involved. More diagnostic tools are required to guarantee that any given computational grid is satisfactory, thereby reducing the number of revisions needed to allow accurate modeling of the physical processes being studied. These tools need to be developed for computational structural mechanics problems as well as for computational fluid dynamics problems. Additional work is needed in the area of unstructured grids in order to allow the generation of unstructured grids to handle viscous flows. Further work in the area of parameterizing surfaces with respect to design variables is needed to shorten the design and preliminary design cycles. Further work in applying adaptive grids is required to model wing tip vortices to help improve designs and flight procedures to save lives.

In addition, expansion of effort in other areas is indicated. New advances in the area of reverse engineering are to be studied. New techniques to relate 2-D CT scans to an accurate 3-D surface representation of a model or structural element are needed. Also, more robust algorithms for surface reconstruction from point clouds measured from laser digitizers are needed. More experience is needed within the GEOLAB team to become more familiar with grids for structural analysis.

As the team works to solve individual task requests, new tools are being generated and existing tools are being improved to increase the efficiency of all aspects of the grid generation process.

5 Conclusions

GEOLAB has become the focal point for geometry issues at Langley. It is providing an essential function for all continuum simulation in a cost effective manner. Researchers do not need to be geometry experts in order to accomplish their mission. GEOLAB has become an interface between Langley Research Center organizations and their customers to allow rapid interchange and use of geometry data. GEOLAB is developing new technology for surface modeling and grid generation, and in addition to using the technology in-house, is transferring it to other NASA, government, university, and industrial organizations.

References

[1] Vedat Akdag and Armin Wulf. Integrated geometry and grid generation system for complex configurations. *Proceedings of the Software Systems for Surface Modeling and Grid Generation*, pages 161–172, April-30,1992. NASA Conference Publication 3143.

[2] R. T. Biedron and J. L. Thomas. A generalized patched-grid algorithm with application to the F-18 forebody with actuated control strake. *Computing Systems in Engineering*, 1(2-4):563–576, 1990.

[3] F. Ghaffari, J. M. Luckring, J. L. Thomas, B. L. Bates, and R. T. Biedron. Multiblock Navier-Stokes solutions about the F/A-18 Wing-LEX-Fuselage configuration. *Journal of Aircraft*, 30(3):293–303, 1993.

[4] W. T. Jones and Jamshid Samareh-Abolhassani. A grid generation system for multi-disciplinary design optimization. *Proceedings of the 12th AIAA Computational Fluid Dynamics Conference*, June 1995. San Diego, California. AIAA Paper 95-1689.

[5] Paresh Parikh, Shahyar Pirzadeh, and Rainald Lohner. A package for 3-D unstructured grid generation, finite-element flow solution and flow field visualization. NASA Contractor Report 182090, September 1990.

[6] S. Pirzadeh. Recent progress in unstructured grid generation. January 1992. AIAA Paper 92-0445.

[7] M.-A. K. Posenau. Approaches to high aspect ratio triangulations. Technical report, NASA Langley Research Center, August 1993. NASA Technical Memorandum 107684.

[8] M.-A. K. Posenau and D. M. Mount. Delaunay triangulation and computational fluid dynamics meshes. Technical report, NASA Langley Research Center, August 1992. NASA Technical Memorandum 107663.

[9] Jamshid Samareh-Abolhassani. GridTool: Surface modeling and grid generation tool. *Workshop for Surface Modeling, Grid Generation, and Related CFD Issues*, May 9-11, 1995. Held at NASA Lewis Research Center.

[10] Jamshid Samerah-Abolhassani. Unstructured grids on NURBS surfaces. *Proceedings 11th Applied Aerodynamics Conference*, August 9-11, 1993. Monterey, California. AIAA Paper 93-3454.

[11] R. Smith, M. Bloor, M. Wilson, and A. Thomas. Rapid airplane parametric input design (RAPID). *Proceedings of the 12th AIAA Computational Fluid Dynamics Conference*, June 1995. San Diego, California. AIAA Paper 95-1687.

[12] John P. Steinbrenner and John R. Chawner. The GRIDGEN version 8 multiple block grid generation software. Technical report, MDA Engineering Inc., Arlington, Texas, December 1992. MDA Engineering Report 92-01.

[13] John P. Steinbrenner, John R. Chawner, and Chris L. Fouts. The GRIDGEN 3D multiple block grid generation system volume 1: Final report. Technical report, Wright Research & Development Center, Wright Patterson AFB, July 1990. WRDC-TR-90-3022.

[14] John E. Stewart and Jamshid Abolhassani. A graphically interactive approach to structured and unstructured surface grid quality analysis. *Proceedings AIAA/AHS/ASEE Aerospace Design Conference*, February 15-18, 1993. Anaheim, California. AIAA Paper 93-3351-CP.

[15] J. L. Thomas, S. L. Krist, and W. K. Anderson. Navier-Stokes computations of vortical flows over low-aspect-ratio wings. *AIAA Journal*, 28(2):205–2123, 1990.

A Software Tool Summary

GEOLAB uses a variety of software for surface modeling, grid generation, and flow field validation of geometry. The purpose of the Appendix is to give the reader an overview of the software. The commercial packages are:

- GRIDGEN
- ICEMCFD
- AZ2000/AZ3000
- PATRAN

Tools developed in GEOLAB available to the U.S. Government, universities, and industry are:

- CONVERT
- CSCMDO
- GridTool
- SCAFFOLD
- SurfACe
- VOLUME

Tools developed at Langely or other NASA facilities and available to the U.S. government, universities and industry are:

- VGRID/USM3D
- TLNS3DMB
- CFL3D

A.1 GRIDGEN

GRIDGEN version 8 is a system of four codes for the generation of 3D, multiple block, structured grids: GRIDGEN version 8 was developed by MDA Corporation and sponsored by the Langley Research Center. The four programs are:

GRIDBLOCK is an interactive code for decomposition of the domain of interest into blocks, distribution of points along edges, and algebraic surface grid generation.

GRIDGEN2D is an interactive code for elliptic PDE refinement of 3D surface grids on the six faces of each block in the system.

GRIDGEN3D is a batch code for the generation of 3D volume grids on the interior of each block in the system.

GRIDVUE3D: Interactive code for inspecting volume grids.

The three interactive codes have been written using the Silicon Graphics IrisGL graphics library for both the user interface (e.g., buttons, text input) and the grid rendering. As such, these codes will only run on hardware that supports IrisGL. Version 8.3 of Gridblock, Version 8.4 of Gridgen2d, Version 8.8 of Gridgen3d, and Version 8.6 of Gridvue3d are currently available.

GRIDGEN version 9 integrates the functions of GRIDBLOCK and GRIDGEN2D into a single interactive program. GRIDGEN version 9 was developed by MDA corporation and sponsored by the AMES Research Center. GRIDGEN version 9 is available from COSMIC.

A.2 ICEMCFD

ICEMCFD is a grid generation system built on top of a full CAD system. Geometry data can either be created within the system or read as either point format or IGES format. The grid is created independent of the geometry and at the end of the process projected directly onto the CAD surface geometry. This patch-independent approach can overlook small gaps and overlaps of the surfaces in the geometry.

ICEMCFD can be used to produce multi-block structured grids, unstructured tetrahedral grids, and body-fitted Cartesian grids. The resulting grids, topology and boundary conditions can be output in a number of formats to match different flow solvers that may be used.

A.3 AZ2000/AZ3000

AZ2000/AZ3000 are software packages developed by Program Development Corporation for generating and displaying two and three dimensional multiblock structured grids. The packages automatically determine the blocking structure around complex geometries and accommodate nested grids. One license for the 3D 500 block, 1 million grid point code has been purchased, for assessment of code capabilities.

A.4 PATRAN

P3/PATRAN is a general purpose three-dimensional Mechanical Computer-Aided Engineering(MCAE) software developed by PDA Engineering. P3/PATRAN provides a graphical environment where geometry can be modeled and pre-processed for analysis; the analysis results can be post-processed within the P3/PATRAN environment. It allows direct access to geometry from CAD systems such as Unigraphics, Pro/ENGINEER, and CATIA or as Initial Graphics Exchange Specification(IGES) entities. It also provides analysis preferences for code specific data input for analysis codes such as ABAQUS, ANSYS, MARC, and MSC/NASTRAN.

A.5 CONVERT

CONVERT is a batch program that allows one to convert grids to/from various formats such as binary, formatted, unformatted, single precision, double precision, PLOT3D, GRIDGEN, LaWGS, Tecplot, etc.

A.6 CSCMDO

CSCMDO is a general multi-block three dimensional volume generator suitable for multidisciplinary design optimization. The code is highly automated, robust, and efficient. Algebraic techniques are used to generate and/or modify face and volume grids to reflect geometric changes resulting from design optimization. Volume grids are generated/modified in a batch environment and controlled via an ASCII user input file. This allows the code to be used directly in the design loop. The code has been written in ANSI "C" to be platform independent. CSCMDO has been tested extensively on aerospace configurations. The test cases range from simple wing/body configurations to full HSCT geometry with tail surfaces, engine nacelles, and canards. The code is also used outside the design loop in the GEOLAB for rapid modification and quality checks of existing CFD volume grids.

A.7 GridTool

GridTool is an interactive program for IRIS workstations. This program has been developed for unstructured and structured grids. In unstructured areas, the code is capable of generating an input file for VGRID systems. Surfaces can be read either in point form such as GRIDGEN, PLOT3D, LaWGS, etc., or NURBS form such as IGES-128. Then, the surfaces are represented internally as NURBS surfaces. Also, the code can be used to project either unstructured or structured surface grids onto NURBS surfaces. There is a batch version available for projecting unstructured and structured surface grids.

A.8 SCAFFOLD

SCAFFOLD is an interactive program that allows surfaces to be constructed from a group of points, such as surface measurements from a laser digitizer or cordax machine. The program accepts x, y, and z point values in the following formats: ECHO (laser digitizer), LaWGS, PLOT3D, and GRIDGEN. A new surface is created first by defining the points along the surface edge by selecting existing points. From the edge points, four edges are specified by selecting four corner points. An m x n mesh is defined by bilinearly interpolating points along the edges and in the interior of the new surface. The mesh is then projected onto the point sample using a normal projection algorithm to obtain the curvature of the original sample. The program also includes other tools to aid in surface development such as surface shading, displaying surface normals, and interactive means to rotate and translate surfaces.

SCAFFOLD is coded in the C programming language and runs on Silicon Graphics Iris workstations. The code is still under development with most of the effort concentrated on automating the process described above. Currently, work is being directed toward developing methods to extract geometry and topology from a group of points to form mathematically represented surfaces. SCAFFOLD is a simple solution to this problem since it provides the tools necessary to develop surfaces that can be manipulated by existing CAD/CAM packages, but it requires heavy user interaction and user knowledge of the topology represented by the sample points. More sophisticated algorithms can be easily incorporated into SCAFFOLD as they become available.

A.9 SurfACe

A Surface Analysis Code (SurfACe) has been developed to help researchers assess surface grid quality of computational grids used in CFD analyses. Anomalies in grids used in these analyses can result in flow solutions that are not consistent with the true flow field characteristics of the vehicle. SurfACe can be used to highlight grid generation errors that are not easily detected in wireframe or shaded representations of a grid and thereby can increase the cost effectiveness of CFD as a design tool.

SurfACe can be used to evaluate both structured and unstructured surface grids on a number of grid quality parameters that indicate changes in surface curvature and changes in surface grid quality. Surface curvature parameters included related to grid smoothness are: the magnitudes of the x-, y-, and z-components of the surface normal vectors, first and second derivatives of these vectors, and the normal, Gaussian, and mean curvatures. Grid quality parameters included related to grid resolution are: surface grid cell area, orthogonality, and aspect ratio. Each parameter is displayed on the geometry using a variable color map. The displays can be viewed dynamically with rotation, translation, and scaling being controlled either by the keyboard or by the mouse. Wireframe, hidden line, and shaded views of the surface grid are also available.

A.10 VOLUME

VOLUME is an interactive program written for IRIS workstations to generate multi-block structured volume grids. The code reads the surfaces of each block in either GRIDGEN or PLOT3D format. A transfinite method is used with the following blending functions: (1) Soni, (2) exponential, and (3) natural log. The unique feature of this program is the capability of not only specifying the boundary surfaces of each block but also the internal surfaces.

A.11 VGRID/USM3D

The VGRID/USM3D aerodynamic analysis system is available for computing the flowfields around complex configurations. VGRID is a robust, user-oriented code for generating unstructured tetrahedral grids around very complex geometries by the Advancing Front Method. USM3D is an upwind flow code for solving the Euler equations on tetrahedral grids. Input for the system is facilitated through the GridTool utility developed by CSC Corporation and available through GEOLAB. The system is widely used and is supported by the Transonic Aerodynamics Branch (Contact: Dr. Neal Frink/804-864-2864).

A.12 TLNS3DMB and CFL3D

Two Reynolds-Averaged Navier-Stokes solvers developed in the Computational Fluid Dynamics Laboratory (B1192) are available for computations on block-structured grids. The two codes, TLNS3DMB and CFL3D, can and have been used extensively for a variety of applications across the Mach number range. The features of the two codes are:

Steady and unsteady strong conservation law forms of compressible flows

Finite-volume discretizations

Euler and Navier-Stokes (laminar and Reynolds-averaged) solvers

Second-order spatial accuracy

Range of turbulence models from algebraic to two-equation models

Full MultiGrid (FMG) acceleration, including grid sequencing, to steady state

Perfect gas equation of state

The TLNS3DMB code has evolved from central-differencing concepts for the convective and pressure terms while the CFL3D code has evolved from upwind-differencing concepts. Both codes treat the viscous terms with central differencing. Either code allows an arbitrary number of generalized coordinate blocks. The CFL3D code has generalized patched and overset grid capabilities while TLNS3DMB requires a one-to-one connection between the grid points of the blocks. A unified input and output format is currently being developed and tested for both codes. Contact: Dr. Chris Rumsey (804-864-2165) for CFL3D and Dr. Veer Vatsa (804-864-2236) for TLNS3DMB.

B In-House Projects

B.1 Rapid Airplane Parametric Input Design (RAPID)

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Abstract

RAPID is a methodology and software system to define a class of airplane configurations and directly evaluate surface grids, volume grids, and grid sensitivity on and about the configurations. A distinguishing characteristic which separates RAPID from other airplane surface modelers is that the output grids and grid sensitivity are directly applicable in CFD analysis. A small set of design parameters and grid control parameters govern the process which is incorporated into interactive software for "real time" visual analysis and into batch software for the application of optimization technology. The computed surface grids and volume grids are suitable for a wide range of Computational Fluid Dynamics (CFD) simulation. The general airplane configuration has wing, fuselage, horizontal tail, and vertical tail components. The double-delta wing and tail components are manifested by solving a fourth order partial differential equation (PDE) subject to Dirichlet and Neumann boundary conditions. The design parameters are incorporated into the boundary conditions and therefore govern the shapes of the surfaces. The PDE solution yields a smooth transition between boundaries. Surface grids suitable for CFD calculation are created by establishing an H-type topology about the configuration and incorporating grid spacing functions in the PDE equation for the lifting components and the fuselage definition equations. User specified grid parameters govern the location and degree of grid concentration. A two-block volume grid about a configuration is calculated using the Control Point Form (CPF) technique. The interactive software, which runs on Silicon Graphics IRIS workstations, allows design parameters to be continuously varied and the resulting surface grid to be observed in real time. The batch software computes both the surface and volume grids and also computes the sensitivity of the output grid with respect to the input design parameters by applying the precompiler tool ADIFOR to the grid generation program. The output of ADIFOR is a new source code containing the old code plus expressions for derivatives of specified dependent variables (grid coordinates) with respect to specified independent variables (design parameters). The RAPID methodology and software provide a means of rapidly defining numerical prototypes, grids, and grid sensitivity of a class of airplane configurations. This technology and software is highly useful for CFD research for preliminary design and optimization processes.

B.2 Algorithms for High Aspect Ratio Oriented Triangulations

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Abstract

Grid generation plays an integral part in the solution of computational fluid dynamics problems for aerodynamics applications. A major difficulty with standard structured grid generation, which produces quadrilateral (or hexahedral) elements with implicit connectivity, has been the requirement for a great deal of human intervention in developing grids around complex configurations. This has led to investigations into unstructured grids with explicit connectivities, which are primarily composed of triangular (or tetrahedral) elements, although other subdivisions of convex cells may be used. The existence of large gradients in the solution of aerodynamic problems may be exploited to reduce the computational effort by using high aspect ratio elements in high gradient regions. However, the heuristic approaches currently in use do not adequately address this need for high aspect ratio unstructured grids.

High aspect ratio triangulations very often produce the large angles that are to be avoided. Point generation techniques based on contour or front generation are judged to be the most promising in terms of being able to handle complicated multiple body objects, with this technique lending itself well to adaptivity. The eventual goal encompasses several phases: first, a partitioning phase, in which the Voronoi diagram of a set of points and line segments (the input set) will be generated to partition the input domain; second, a contour generation phase in which body-conforming contours are used to subdivide the partition further as well as introduce the foundation for aspect ratio control, and; third, a Steiner triangulation phase in which points are added to the partition to enable triangulation while controlling angle bounds and aspect ratio. This provides a combination of the advancing front/contour techniques and refinement. By using a front, aspect ratio can be better controlled. By using refinement, bounds on angles can be maintained, while attempting to minimize the number of Steiner point.